PATENT APPLICATION

of

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for a

BLIND SPEECH USER INTERFERENCE CANCELLATION (SUIC) FOR HIGH SPEED DOWNLINK PACKET ACCESS (HSDPA)

BLIND SPEECH USER INTERFERENCE CANCELLATION (SUIC) FOR HIGH
SPEED DOWNLINK PACKET ACCESS (HSDPA)

Field of the Invention

This invention generally relates to a blind speech user interference cancellation
5   for high speed downlink packet access (HSDPA) and more specifically to detecting a
desired HSDPA signal by a hard-decision and an interfering speech user signal by a soft-
decision using multistage processing.

Background of the Invention

1. Field and background of the invention

10   High speed downlink packet access (HSDPA) described in 3GPP TR25.858
V5.0.0 (2002-3), "High speed downlink packet access: Physical layer aspects (Rel5)",
also known as Rel5, is underway supporting the evolution of third-generation systems to
meet the rapidly developing needs on high data rate. Various technologies are considered
in HSDPA proposals such as adaptive modulation and coding (AMC), hybrid automatic
15   repeat request (HARQ), fast cell selection (FCS), multiple input multiple output (MIMO)
antenna processing and multicode transmission. HSDPA user equipment (UE) is
suffering from multiple access interference (MAI) induced by its own multiple spreading
codes and speech user interference (SUI) induced by a co-existing interfering speech user
signal also known, for example, as Rel99 according to 3GPP TR25.101, "UE Radio
20   Transmission and Reception (FDD)".

A comprehensive multiuser detection methods to suppress interference can be
found in S. Verdú, *Multiuser Detection*: Cambridge University Press, 1998. Most of them
are proposed for uplink communications with the knowledge of all the spreading codes.
The HSDPA UE only knows its own spreading codes in multicode transmission,
25   allocated power and modulation alphabet and has no knowledge of the interfering speech
user signal. That is why blind speech user interference cancellation for suppressing the
SUI is a major challenge.

Blind multiuser detectors require no training data sequence, only the knowledge
of the desired user spreading code. A blind adaptive MMSE (minimum mean-square
30   error) multiuser detector is introduced by M. Honig, U. Madhow, and S. Verdú "Blind
adaptive multiuser detection," *IEEE Trans. Inform. Theory*, vol. 41, pp. 944–960, July

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1995. A subspace approach for blind multiuser detection is presented by X. Wang and V. Poor, "Blind multiuser detection: a subspace approach," *IEEE Trans. Inform. Theory*, vol. 44, pp. 677–690, Mar. 1998, where both the decorrelating and the MMSE detector are obtained blindly. A blind solution based on higher order statistics and nonlinear

5   cancellation is presented by D. Samardzija, N. Mandayam, and I. Seskar, "Nonlinear adaptive blind interference cancellation for DS-CDMA systems," in *The IEEE Vehicular Technology Conf.e (VTC)*, Boston, MA, Sept. 2000. Alternative adaptive and blind solutions have been analyzed by S. Ulukus and R. Yates, "A blind adaptive decorrelating detector for CDMA systems," *IEEE J. Select. Areas Commun.*, vol. 16, pp. 1530–1541,

10   Oct. 1998, and overviewed by U. Madhow, "Blind adaptive interference suppression for direct-sequence CDMA," in *Proc. IEEE*, Special Issue on Blind Identification and Equalization, Oct. 1998, pp. 2049–2069.

These proposed adaptive receivers are based mostly on the linear MMSE criterion. Through the central limit theorem, the SUI tends to be a Gaussian random

15   process when the number of interfering speech users with random time delay is high enough. In this case, the MMSE principle leads to minimization of error probability. However, most of the base station (BS) transmission power and spreading codes will be assigned to a high speed user in HSDPA with a reasonably lower number of speech users in practical synchronous DL transmission. In this situation, the SUI does not tend to be

20   Gaussian distributed, which triggers the research and development on SUI detection and nonlinear interference cancellation.

2. System Model

The discrete-time received signal at HSDPA UE can be presented as

$$\mathbf{r} = \mathbf{H}\left(\mathbf{S}_h\mathbf{A}_h\mathbf{b}_h + \mathbf{S}_s\mathbf{A}_s\mathbf{b}_s + \mathbf{s}_p\mathbf{A}_p\mathbf{b}_p\right) + \mathbf{n} \in C^{P\times 1} \tag{1}$$

wherein $\mathbf{H} \in C^{P\times P}$ is a matrix containing multipath channel impulse response in a time

25   domain, $P = R_{chip} \times T_{TTI}$ is a number of chips per transmission time interval (TTI) with $R_{chip} = 3.84 Mcps$ (typical value) is the chip rate and $T_{TTI} = 2ms$ (typical value) is the time period of TTI, C is a complex space, $\mathbf{n} \in C^{P\times 1}$ is a noise vector.

$$S_h = diag\left(\overbrace{\hat{S}_h,\cdots,\hat{S}_h}^{P/SF_1}\right) \in \Re^{P \times L_h}$$ is a block-based diagonal matrix over one TTI, wherein

SF_1=16 (typical value) is a spreading factor (SF) of a desired HSDPA signal with known

spreading codes, $L_h = \dfrac{P}{SF_1} N_h$ is a number of HSDPA parallel data symbols transmitted per

TTI, N_h is a number of assigned multicodes, $\Re$ is a real value space,

5    $\hat{S}_h = [s_1^h; s_2^h; \cdots; s_{N_h}^h] \in \Re^{SF_1 \times N_h}$ is a spreading code matrix over one HSDPA symbol period,

$s_i^h \in \Re^{SF_1 \times 1}$ is an ith assigned SF_1-bit Walsh code vector, $A_h \in \Re^{L_h \times L_h}$ is a diagonal matrix

with HSDPA symbol energy, $b_h \in C^{L_h \times 1}$ is a transmitted HSDPA symbol vector per TTI.

$$S_s = diag\left(\overbrace{\hat{S}_s,\cdots,\hat{S}_s}^{P/SF_2}\right) \in \Re^{P \times L_s}$$ is a block-based diagonal matrix over one TTI, wherein

SF_2=128 (typical value) is a spreading factor of an interfering speech user signal with

10   unknown spreading codes, $L_s = \dfrac{P}{SF_2} N_s$ is a number of interfering speech user parallel data

symbols transmitted per TTI, N_s is a number of co-existing interfering speech users,

$\hat{S}_s = [s_1^s; s_2^s; \cdots; s_{N_s}^s] \in \Re^{SF_2 \times N_s}$ is a spreading code matrix over one interfering speech user

symbol period, $s_i^s \in \Re^{K_2 \times 1}$ is the ith assigned SF_2-bit Walsh code vector, $A_s \in \Re^{L_s \times L_s}$ is a

diagonal matrix with interfering speech user symbol energy, $b_s \in C^{L_s \times 1}$ is a transmitted

15   interfering speech user symbol vector per TTI.

$$s_p = \left[\overbrace{\hat{s}_p,\cdots,\hat{s}_p}^{P/SF_3}\right] \in \Re^{P \times 1}$$ is a spreading vector for a common pilot channel

(CPICH), wherein SF_3=256 (typical value) is a spreading factor of a pilot signal, $L_p = \dfrac{P}{SF_3}$

is a number of parallel pilots per TTI, $\hat{s}_p \in \Re^{SF_3 \times 1}$ is one assigned K_3-bit Walsh code vector,

$A_p \in \Re^{L_p \times L_p}$ is a diagonal matrix with pilot energy, $b_p \in C^{L_p \times 1}$ is a pilot vector per TTI.

3. Conventional RAKE receiver

The conventional RAKE receiver (RAKER) neglects the MAI induced by its own spreading codes and SUI induced by co-existing interfering speech users and CPICH interference so Equation 1 can be rewritten for the RAKER as follows

$$\mathbf{r}_{raker} = \mathbf{HS}_h\mathbf{A}_h\mathbf{b}_h + (\mathbf{I}_{MAI} + \mathbf{I}_{SUI} + \mathbf{I}_{CPICH}) + \mathbf{n}, \tag{2}$$

5   so that a hard-decision (HD) data estimated by RAKER can be written as

$$\hat{\mathbf{b}}_{raker} = \text{dec}(\mathbf{z}) = \text{dec}(\mathbf{A}_h^H\mathbf{S}_h^H\mathbf{H}^H\mathbf{r}_{raker}), \tag{3}$$

Wherein dec() is a decision device based on modulation alphabets, $\mathbf{z}$ is a SD output of RAKER, and $()^H$ denotes a complex conjugate transpose operation.

Common Pilot cancellation in UE has recently gained attention for CDMA cellular networks and it has been shown that the network capacity can be significantly

10   improved as described in 3GPP TR 25.991: Feasibility study on the mitigation of the effect of the common pilot channel (CPICH) interference at the user equipment, 2002, and in 3GPP R4-01-1232, Motorola, "CPICH Cancellation Complexity."

Since the UE has the knowledge of the CPICH on power, spreading codes and pilot symbols for channel estimation, the interference induced by the CPICH can be

15   subtracted directly as follows

$$\tilde{\mathbf{r}} = \mathbf{r} - \mathbf{I}_{CPICH} = \mathbf{r} - \mathbf{HS}_p\mathbf{A}_p\mathbf{b}_p. \tag{4}$$

Then the same RAKER principle of Equation 3 can be applied for the received signal with CPICH interference cancellation described by Equation 4.

4. Conventional PIC receiver

In contrast to the RAKE receiver, a conventional parallel interference cancellation

20   (PIC) receiver described by M.K. Varanasi and B. Aazhang, "Multistage detection for asynchronous code-division multiple-access communications," *IEEE Transactions on Communications,* COM-38(4), Apr. 1990, suppresses the MAI induced by its own spreading codes with the knowledge of allocated power, assigned spreading codes and modulation alphabet. However, it still neglects SUI induced by the co-existing interfering

25   speech users and CPICH interference. Using the conventional RAKER output as the

initial estimates as $\hat{b}_{pic}(0) = \hat{b}_{raker}$, the hard-decision data estimates of PIC at m^{th} stage can be described as

$$\hat{b}_{pic}(m) = \text{dec}(z - F\hat{b}_{pic}(m-1)) \qquad (5)$$

wherein $F = G - \text{diag}(G)$ is the off-diagonal matrix, $\text{diag}(\ )$ denotes diagonal elements of the matrix, $G = A_h^H S_h^H H^H H S_h A_h$ is the cross-correlation matrix.

5   Summary of the Invention

The object of the present invention is to provide a blind speech user interference cancellation (SUIC) for a high speed downlink packet access (HSDPA).

According to a first aspect of the present invention, a method of a blind speech user interference cancellation (SUIC) for a high speed downlink packet access (HSDPA)

10   comprising the steps of: receiving an input signal in a discrete-time domain by a receiving and storing means of a blind SUIC receiver; and separating the input signal to a desired HSDPA signal with known spreading codes and to an interfering speech user signal with unknown spreading codes using a Walsh correlator of the blind SUIC receiver for further processing.

15   In further accord with the first aspect of the invention, the receiving and storing means having a memory buffer for storing the input signal.

Still further according to the first aspect of the invention, the method further comprises the steps of: generating a speech user interference signal by a soft-decision on the interfering speech user signal using an SUI estimation means of the blind SUIC

20   receiver; generating an adjusted signal by subtracting the SUI signal from the input signal using a first adder; and providing the adjusted signal to the Walsh correlator.

Further still according to the first aspect of the invention, the method further comprises the steps of: separating the adjusted signal to a further desired HSDPA signal with the known spreading codes and a further interfering speech user signal with the

25   unknown spreading codes using a Walsh correlator; and generating a soft-decision HSDPA signal from the further desired HSDPA signal using a one-stage soft-decision parallel interference cancellation (SD-PIC) receiver. Also further, the soft-decision

HSDPA signal (37) is a blind SUIC receiver output signal if a final multistage is reached based on predetermined criteria.

According further to the first aspect of the invention, the method further comprises the steps of: generating a hard-decision HSDPA signal based on the soft-decision HSDPA signal using a hard-decision means; generating a multiple access interference (MAI) signal based on the hard-decision HSDPA signal (38) using an MAI estimation means of the blind SUIC receiver; generating a further adjusted signal by subtracting the MAI signal from the input signal using a second adder; and providing the further adjusted signal to further Walsh correlator.

Yet further still according to the first aspect of the invention, the method further comprises the step of generating a soft-decision HSDPA signal from the desired HSDPA signal using a one-stage soft-decision parallel interference cancellation (SD-PIC) receiver. Further, the soft-decision HSDPA signal is a blind SUIC receiver output signal, if a final multistage is reached based on predetermined criteria.

According further still to the first aspect of the invention, the method further comprises the steps of: generating the hard-decision HSDPA signal based on the soft-decision HSDPA signal using a hard-decision means; generating a multiple access interference (MAI) signal based on the hard-decision HSDPA signal using an MAI estimation means of the blind SUIC receiver; generating an adjusted signal by subtracting the MAI signal from the input signal using a first adder; and providing the adjusted signal to the Walsh correlator.

In further accord with the first aspect of the invention, the method further comprises the steps of: separating the adjusted signal to a further desired HSDPA signal with the known spreading codes and a further interfering speech user signal with the unknown spreading codes using a Walsh correlator; generating a speech user interference (SUI) signal by a soft-decision on the further interfering speech user signal using an SUI estimation means of the blind SUIC receiver; generating a further adjusted signal by subtracting the SUI signal from the input signal using a second adder; and providing the further adjusted signal to a further Walsh correlator.

According to a second aspect of the invention, a blind speech user interference cancellation (SUIC) receiver for a high speed downlink packet access (HSDPA) comprises: a Walsh correlator, responsive to an input signal in a discrete-time domain,

for providing two signals for a further processing by separating the input signal to a desired HSDPA signal with known spreading codes and to an interfering speech user (ISU) signal with unknown spreading codes; and receiving and storing means, responsive to the input signal, for storing the input signal and for providing the input signal to the

5   Walsh correlator.

According further to the second aspect of the invention, the blind speech user interference cancellation (SUIC) receiver further comprises: an SUI estimation means, responsive to the interfering speech user signal, for providing a speech user interference (SUI) signal by a soft-decision on the interfering speech user signal; and a first adder,

10   responsive to the SUI signal and to the input signal, for providing an adjusted signal to the Walsh correlator by subtracting the SUI signal from the input signal, wherein the Walsh correlator provides a further desired HSDPA signal with the known spreading codes and a further interfering speech user (ISU) signal with the unknown spreading codes.

15   Further according to the second aspect of the invention, the blind speech user interference cancellation (SUIC) receiver further comprises a one-stage soft-decision parallel interference cancellation (SD-PIC) receiver, responsive to the further desired HSDPA signal, for providing a soft-decision HSDPA signal. Further, the soft-decision HSDPA signal becomes a blind SUIC receiver output signal based on predetermined

20   criteria.

Further still according to the second aspect of the invention, the blind speech user interference cancellation (SUIC) receiver further comprises: a hard-decision means, responsive to the soft-decision HSDPA signal, for providing a hard-decision HSDPA signal; an MAI estimation means, responsive to the hard-decision HSDPA signal, for

25   providing a multiple access interference (MAI) signal; and a second adder, responsive to the MAI signal and to the input signal, for providing a further adjusted signal by subtracting the MAI signal from the input signal, wherein the further adjusted signal is provided to a further Walsh correlator.

In further accord with the second aspect of the invention, the blind speech user

30   interference cancellation (SUIC) receiver further comprises a one-stage soft-decision parallel interference cancellation (HD-PIC) receiver, responsive to the desired HSDPA

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signal, for providing a soft-decision HSDPA signal. Further, the soft-decision HSDPA signal becomes a blind SUIC receiver output signal based on predetermined criteria.

Further still according to the second aspect of the invention, the blind speech user interference cancellation (SUIC) receiver further comprises: a hard-decision means,

5   responsive to the soft-decision HSDPA signal, for providing a hard-decision HSDPA signal; an MAI estimation means, responsive to the hard-decision HSDPA signal, for providing a multiple access interference (MAI) signal; and a first adder, responsive to the MAI signal and to the input signal, for providing a further adjusted signal to the Walsh correlator by subtracting the MAI signal from the input signal, wherein the Walsh

10   correlator provides a further desired HSDPA signal with known spreading codes and a further interfering speech user signal with unknown spreading codes.

In further accordance with the second aspect of the invention, the blind speech user interference cancellation (SUIC) receiver further comprises: an SUI estimation means, responsive to the further interfering speech user signal, for providing a speech

15   user interference (SUI) signal by a soft-decision on the further interfering speech user signal; and a second adder, responsive to the SUI signal and to the input signal, for providing a further adjusted signal to a further Walsh correlator by subtracting the SUI signal from the input signal.

Brief Description of the Drawings

20   For a better understanding of the nature and objects of the present invention, reference is made to the following detailed description taken in conjunction with the following drawings, in which:

Figure 1 is a block diagram representing a full Walsh transform matrix setup, according to the present invention.

25   Figure 2a is a block diagram representing a blind pre-SUIC receiver, according to the present invention.

Figure 2b is a block diagram representing a blind post-SUIC receiver, according to the present invention.

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Figure 3a shows a flow chart illustrating operation of a blind pre-SUIC receiver, according to the present invention.

Figure 3b shows a flow chart illustrating operation of a blind post-SUIC receiver, according to the present invention..

5   Best Mode for Carrying Out the Invention

An advanced nonlinear blind speech user interference cancellation (SUIC) receiver, which jointly detects a desired HSDPA signal by a hard-decision (HD) and an interfering speech user signal by a soft-decision (SD) using multistage processing, is described in this invention. In the disclosed blind SUIC receiver, a full Walsh transform

10   correlator is used instead of a conventional RAKE receiver (RAKER), where the outputs are categorized into two parts: the desired HSDPA signal with known spreading codes and the interfering speech user (ISU) signal with unknown spreading codes, respectively. HSDPA user equipment (UE) has no knowledge of the number of co-existing interfering speech users, their powers due to a power control, their spreading codes and related

15   modulation constellations. That is why only the soft-decision is made over the interfering speech user signal output of the Walsh correlator. Based on that soft-decision, a speech user interference (SUI) is regenerated and subtracted from the received signal, correspondingly. In contrast, the hard-decisions are made over the desired HSDPA signal output of the Walsh correlator (the same as the outputs of the conventional RAKER) over

20   the SUI-free signal with the knowledge of allocated power and modulation alphabet. The hard-decisions of RAKER are used as initial estimates and a conventional parallel interference cancellation (PIC) is applied to suppress a multiple access interference (MAI). The joint detection on both the HD of the desired HSDPA signal and the SD of the interfering speech user signal can be repeated using multiple stages until a predefined

25   number of stages is reached which relates to predetermined criteria, for example, a targeted convergence rate or a targeted bit error rate (BER). The order of the joint detection in the blind SUIC receiver can be varied such that the HD of the desired HSDPA signal is estimated first and the induced MAI is regenerated and subtracted and then the SD of the interfering speech user signal is estimated over the MAI-free received

30   signal.

Figure 1 is a block diagram representing an example of a full Walsh transform matrix setup, according to the present invention. In one scenario shown in Figure 1, a full 16x16 Walsh transform correlator (referred to as a Walsh correlator) is used to detect both the desired HSDPA signal with known spreading codes represented by an HSDPA

5   matrix S_h 10 and the interfering speech user (ISU) signal with unknown spreading codes represented by an ISU matrix S_r 12, respectively. Referring to Equation 1, for the example of Figure 1, the following assumptions are made: T_{chip}=3.84 Mcps, T_m=2ms, P=7680, SF_1=16, SF_2=128, and SF_3=256.

Then a discrete-time received signal **r** represented by a matrix **S** 16 at the HSDPA

10   UE can be simplified from Equation 1 as follows

$$\mathbf{r} = \mathbf{HSd} + \mathbf{n} , \tag{6}$$

wherein $\mathbf{S} = diag\left(\overbrace{\hat{\mathbf{S}}, \cdots, \hat{\mathbf{S}}}^{480=7680/16} \right) \in \mathfrak{R}^{P\times P}$ with $\hat{\mathbf{S}} = \begin{bmatrix} \hat{\mathbf{S}}_h & \hat{\mathbf{S}}_r \end{bmatrix}$ is a full 16x16 Walsh matrix,

$\mathbf{d} = \overbrace{\mathbf{d}_1, \cdots, \mathbf{d}_j, \cdots, \mathbf{d}_{480}}^{480=7680/16} \in C^{P\times 1}$ is a vector including HSDPA and ISU symbols, $\mathbf{d}_j = \begin{bmatrix} \mathbf{d}_h^j & \mathbf{d}_r^j \end{bmatrix}$

is a vector over j^{th} 16-chip period, $\mathbf{d}_h^j = \mathbf{A}_h^j \mathbf{b}_h^j$ is a vector of HSDPA symbols and allocated power, and $\mathbf{d}_r^j$ is a vector of combined ISU soft-decision symbols. Each diagonal member

15    $\hat{\mathbf{S}}$ 16a is a product of $\hat{\mathbf{S}}_h$ 17a and $\hat{\mathbf{S}}_r \in \mathfrak{R}^{16\times(16-N_h)}$ 18a, wherein $\hat{\mathbf{S}}_h$ is a 16-bit Walsh code representing HSDPA users and $\hat{\mathbf{S}}_r$ is a remainder of the 16-bit Walsh code representing ISUs. Equation 6 is also based on the fact that over the 16-chip period, a CPICH matrix s_p 14 is identical to one column of the matrix S_r 12.

The ISU symbols are always periodically orthogonal to the HSDPA symbols over

20   a 16-chip interval. However, the orthogonality of the 128-bit Walsh code of the co-existing ISUs is destroyed over a 16-chip time period, where some of them are identical and these identical sections could be combined. Then the partial matrix of ISU over 16 chips could be condensed into a 16x16 full Walsh matrix by merging with the spreading matrix of the HSDPA.

25   The symbols of these interfering speech users are overlapped over the 16 chips as well. Even though the interfering speech user signals are normally fixed to a QPSK modulation, the modulation constellation points are still deviated due to a symbol

overlapping. Additionally, the HSDPA UE has no knowledge of the number of co-existing interfering speech users, their powers due to a power control, and spreading codes. It makes the HD impossible for ISU symbol estimates. However, it doesn't matter because, according to this invention, SUI is regenerated by SD symbol estimates.

5   Figure 2a is a block diagram representing a blind pre-SUIC receiver **20**, according to the present invention.

An input signal **r 22** is received and stored by a receiving and storing means **24**. The receiving and storing means **24** provides the input signal **22** to the Walsh correlators **32, 32a**, etc. The outputs of the full 16x16 Walsh correlator **32** of a first stage **20a** of the

10   blind pre-SUIC receiver **20**, according to the present invention, are categorized into two parts: the desired HSDPA signal **34** with known spreading codes and the interfering speech user (ISU) signal **48** with unknown spreading codes, respectively. The soft-decision symbol on the ISU signal **48, 48a** at m^{th} stage using the example presented in Figure 1, can be estimated by an SUI estimation means **46** as

$$\hat{\mathbf{d}}_r(m) = \mathbf{S}_r^H \mathbf{H}^H \mathbf{r}, \tag{7}$$

15   wherein $\mathbf{S}_r = diag\left(\overbrace{\hat{\mathbf{S}}_r, \cdots, \hat{\mathbf{S}}_r}^{480=7680/16}\right) \in \Re^{P \times L_r}$ and $L_r = 480 \times (16 - N_h)$. Based on the soft-decision on

the ISU signal **48**, the SUI is regenerated by the SUI estimation means **46**, forming an SUI signal **52**. The SUI signal **52** is subtracted from the received signal **22** using a first adder **28** generating an adjusted signal **30** as follows

$$\tilde{\mathbf{r}} = \mathbf{r} - \mathbf{H}\mathbf{S}_r\hat{\mathbf{d}}_r(m). \tag{8}$$

The adjusted signal **30** is further provided to the Walsh correlator **32**, which

20   separates the adjusted signal **30** to a further desired HSDPA signal with the known spreading codes and a further interfering speech user (ISU) signal with the unknown spreading codes. A soft-decision HSDPA signal **37** generated by a one-stage soft-decision conventional parallel interference cancellation (SD-PIC) receiver **36** on the SUI-free further desired HSDPA signal can be written (similar to the HD-PIC data estimate of

25   Equation 5) as

$$\tilde{\mathbf{b}}_{pic}(m) = \tilde{\mathbf{z}} - \mathbf{F}\hat{\mathbf{b}}_{init}, \tag{9}$$

where $\tilde{z} = A_h^H S_h^H H^H \tilde{r}$ and $\hat{b}_{init} = dec(\tilde{z})$. If the final stage of processing is reached, the soft-decision HSDPA signal **37** is an output of the blind SUIC receiver **20** for further processing (i.e. demodulation and channel decoding). Otherwise, in contrast to the soft-decision (SD) on the ISU signal **48**, a hard-decision HSDPA signal **38** is generated by a

5   hard-decision means **41** on the soft-decision HSDPA signal **37** as

$$\hat{b}_{pic}(m) = dec(\tilde{b}_{pic}(m)). \tag{9a}$$

The further processing proceeds as follows. The hard-decision HSDPA signal **38** is regenerated, forming an MAI signal **42** using an MAI estimation means **40**. Said MAI signal **42** is subtracted from the received signal **22** forming a further adjusted signal **60** by

10   a second adder **58** as

$$\hat{r} = r - HS_r A_r \hat{b}_{pic}(m). \tag{10}$$

The further adjusted signal **60** is provided to a second stage **20b** of the blind pre-SUIC receiver **20**. The second stage **20b** is identical to the first stage **20a**. Then, the second stage **20b** provides the more reliable SD on the ISU signal **48a**, obtained from the received signal **60** with HSDPA MAI cancellation on the first stage **20a** as

$$\hat{d}_r(m) = S_r^H H^H \hat{r} . \tag{11}$$

15   The above mentioned processing (Equations 7 through 11) for joint detection by the HD on the desired HSDPA and by the SD on the ISU signals can be repeated using multiple stages until the predefined number of stages is reached, which relates to a targeted convergence rate or to a targeted bit error rate (BER). Equations 7 through 11 represent only one estimation method among many others, which can be used based on

20   the present invention.

According to the present invention, it follows from Figure 1 that the SUIC UE combines and condenses the fractional parts of both 128-bit Walsh code for the ISUs and 256-bit Walsh code for the CPICH. Therefore, during the iterative SUI estimation and cancellation in the blind SUIC receiver **20**, the interference induced by the CPICH is also

25   suppressed so that there is no need for an additional CPICH cancellation.

Figure 2b is a block diagram representing a blind post-SUIC receiver **21**, according to the present invention. The performance of a post blind post-SUIC receiver **21** is similar to the performance of the blind pre-SUIC receiver **20**. Equations 7-11 are

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applicable to the appropriate blocks of the blind post-SUIC receiver **21**. The difference is that in the blind post-SUIC receiver **21**, the order of the joint detection in the blind-SUIC receiver is varied such that the HD of the desired HSDPA signal is estimated first and the induced MAI is regenerated and subtracted and then the SD of the interfering speech user

5   signal is estimated over the MAI-free received signal.

In particular, the outputs of the full 16x16 Walsh correlator **32** of a first stage **21a** of the blind pre-SUIC receiver **21**, according to the present invention, are categorized into two parts: the desired HSDPA signal **66** with the known spreading codes and the interfering speech user (ISU) signal **70** with the unknown spreading codes, respectively.

10   A soft-decision HSDPA signal **67** is generated by the one-stage SD-PIC receiver **36** using the desired HSDPA signal **66**. If the final stage of processing is reached, the soft-decision HSDPA signal **67** is an output of the proposed blind SUIC receiver **21** for further processing (i.e. demodulation and channel decoding). Otherwise, the further processing proceeds as follows. A hard-decision HSDPA signal **68** is generated by a hard-decision

15   means **41** on the soft-decision HSDPA signal **67**. The hard-decision HSDPA signal **38** is regenerated, forming an MAI signal **74** using the MAI estimation means **40**. Said MAI signal **74** is subtracted from the received signal **22** forming an adjusted signal **64** by the first adder **28**. The adjusted signal **64** is further provided to the Walsh correlator **32**, which separates the adjusted signal **64** to a further desired HSDPA signal with known

20   spreading codes and a further interfering speech user (ISU) signal with unknown spreading codes. Based on the soft-decision on the further ISU signal **70**, the SUI is regenerated by the SUI estimation means **46**, forming an SUI signal **72**. The SUI signal **72** is subtracted from the received signal **22** using a second adder **58** generating a further adjusted signal **76**. The further adjusted signal **76** is provided to a second stage **21b** of the

25   blind post-SUIC receiver **21**, which is identical to the first stage **21a**.

Figure 3a shows a flow chart illustrating operation of a blind pre-SUIC receiver of Figure 2a, according to the present invention. In a method according to the present invention, in a first step **100**, the input signal **r 22** is received and stored by the receiving and storing means **24**. In a next step **102**, the receiving and storing means **24** provides the

30   input signal **22** to the Walsh correlator **32**. In a next step **104**, the Walsh correlator **32** of a first stage **20a** of the blind pre-SUIC receiver **20** separates the input signal **22** to the desired HSDPA signal **34** with known spreading codes and to the interfering speech user (ISU) signal **48** with unknown spreading codes, respectively. In a next step **106**, the SUI

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estimation means **46** generates the SUI signal **52** using the soft-decision on the ISU signal **48**. In a next step **107**, the first adder **28** generates the adjusted signal **30** by subtracting the SUI signal **52** from the received signal **22**. In a next step **108**, the adjusted signal **30** is provided to the Walsh correlator **32**. In a next step **110**, the Walsh correlator **32** separates

5   the adjusted signal **30** to the further desired HSDPA signal with the known spreading codes and to the further ISU signal with the unknown spreading codes. In a next step **112**, the soft-decision HSDPA signal **37** is generated by the one-stage SD-PIC receiver **36** using the further desired HSDPA signal. In a next step **114**, it is ascertained whether further processing is required based on the predetermined criteria, for example, the

10   targeted convergence rate or desired BER. As long as no further processing is required, the soft-decision HSDPA signal **37** becomes the output of the blind SUIC receiver **20**. However, if it is ascertained that further processing is required, in a next step **115**, the hard-decision HSDPA signal **38** is generated by the hard-decision means **41** using the soft-decision HSDPA signal **37**. In a next step **116**, the MAI signal **42** is generated using

15   the MAI estimation means **40** based on the hard-decision HSDPA signal **38**. Said MAI signal **42** is subtracted from the received signal **22** forming the further adjusted signal **60** by the second adder **58**. Finally, in a step **120**, the further adjusted signal **60** is sent to the Walsh correlator **32a** of the second stage **20b** of the blind pre-SUIC receiver **20** and the process repeats.

20   Figure 3b shows a flow chart illustrating operation of a blind post-SUIC receiver, according to the present invention. In a method according to the present invention, in a first step **100**, the input signal **r 22** is received and stored by the receiving and storing means **24**. In a next step **102**, the receiving and storing means **24** provides the input signal **22** to the Walsh correlator **32**. In a next step **104**, the Walsh correlator **32** of a first stage

25   **21a** of the blind pre-SUIC receiver **21** separates the input signal **22** to the desired HSDPA signal **66** with known spreading codes and to the interfering speech user (ISU) signal **70** with unknown spreading codes, respectively.

In a next step **120**, the soft-decision HSDPA signal **67** is generated by the one-stage SD-PIC receiver **36** using the desired HSDPA signal **66**. In a next step **122**, it is

30   ascertained whether further processing is required based on the predetermined criteria, for example, the targeted convergence rate or desired BER. As long as no further processing is required, the soft-decision HSDPA signal **67** becomes the output of the blind post-SUIC receiver **21**. However, if it is ascertained that further processing is required, in a

next step **123**, the hard-decision HSDPA signal **68** is generated by the hard-decision means **41** using the soft-decision HSDPA signal **67**. In a next step **124**, the MAI signal **74** is generated using the MAI estimation means **40** based on the hard-decision HSDPA signal **68**. In a next step **126**, said MAI signal **74** is subtracted from the received signal **22** forming the adjusted signal **64** by the first adder **28**. In a next step **127**, the adjusted signal **64** is provided to the Walsh correlator **32**. In a next step **128**, the Walsh correlator **32** separates the adjusted signal **64** to the further desired HSDPA signal with the known spreading codes and to the further ISU signal with the unknown spreading codes. In a next step **130**, the SUI estimation means **46** generates the SUI signal **72** using the soft-decision on the further ISU signal. In a next step **132**, the second adder **58** generates the further adjusted signal **76** by subtracting the SUI signal **72** from the received signal **22**. Finally, in a step **134**, the further adjusted signal **76** is sent to the Walsh correlator **32a** of the second stage **21b** of the blind pre-SUIC receiver **21** and the process repeats.